JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 2001, **75,** 15–23 NUMBER 1 (JANUARY)

BEHAVIORAL MOMENTUM IN COMPUTER-PRESENTED DISCRIMINATIONS IN INDIVIDUALS WITH SEVERE MENTAL RETARDATION

WILLIAM V. DUBE AND WILLIAM J. MCILVANE

UNIVERSITY OF MASSACHUSETTS MEDICAL SCHOOL–SHRIVER CENTER

Behavioral momentum was examined in 2 individuals with severe mental retardation via within-subject manipulations of obtained reinforcer rates. Subjects performed self-paced discrimination problems presented on a touch screen computer monitor. Two different problems, Tasks A and B, alternated in blocks of 15 trials on a multiple schedule. Reinforcers were snack foods. The reinforcement schedule for Task A was continuous (fixed-ratio 1), and the schedule for Task B was continuous in some conditions and variable ratio in other conditions. Behavioral momentum was assessed in test sessions by prefeeding, presenting response-independent food, and making available alternatives to the tasks. When the obtained reinforcer rate for Task A was at least twice that for Task B, resistance to change was greater for Task A. When both reinforcer rates and response rates were approximately equal for the two tasks, resistance to change was approximately equal. These results are consistent with behavioral momentum effects. They extend previous findings with humans by examining momentum in self-initiated discrete-trial discrimination tasks with ratio schedules, and by isolating relative reinforcer rates as a controlling variable via within-subject manipulations.

Key words: behavioral momentum, multiple schedules, variable-ratio schedules, mental retardation, computer mouse click, screen touch, humans

Nevin's (1992; Nevin & Grace, 2000) behavioral momentum analysis draws an analogy between physical motion and behavioral persistence. In classical mechanics, the degree to which an outside force can perturb the motion of a moving body depends upon its momentum. Momentum is directly proportional to mass, and thus increasing mass increases the resistance to change. Nevin suggested a parallel in the discriminated operant. Rate of responding is analogous to velocity, and the resistance of that rate to disruption by a perturbing operation (prefeeding, reduced reinforcement, alternative reinforcement, etc.) can be used to index the analogue of mass. For a multiple schedule with different rates of reinforcement in two alternating components, previous research indicates that resistance to change (a) is greater in the component with the higher reinforcement rate and (b) appears to be determined primarily by stimulus–reinforcer relations and independently of response rate.

The momentum analysis has been derived and elaborated from work with laboratory animals (e.g., Grace & Nevin, 1997; Nevin, Mandell, & Atak, 1983; Nevin, Tota, Torquato, & Shull, 1990). Three studies with humans have demonstrated momentum effects under laboratory conditions (Cohen, 1996; Dube, Mazzitelli, Lombard, & McIlvane, 2000; Mace et al., 1990; for other applications of the momentum metaphor to human behavior see Mace, 1996; Mace, Lalli, Shea, & Nevin, 1992; Nevin, 1996; Plaud & Gaither, 1996). The experimental design of the present study is similar in some respects to that of Mace et al. (1990), which demonstrated behavioral momentum in 2 individuals with mental retardation. In Mace et al., subjects sorted red plastic dinnerware in one component of a multiple schedule and green dinnerware in the other component. Different variable-interval (VI) schedule values were programmed in each component. The disrupter was an interesting videotape played while subjects were sorting. The rate of sorting fell for both colors, but it decreased less for the color that

Data collection and manuscript preparation were supported in part by NICHD Grants HD 25995 and HD 33802. For their help with session preparation, data collection, or data analysis, we thank Aranya Albert, Lyn Balsamo, Eileen Caffery, Kevin Farren, Paul Filkins, Tom Fowler, Fay Iennaco, Joanne Kledaras, Kristin Lombard, Alison McVay, and Sharon Wang. We also thank The Protestant Guild Learning Center and The New England Center for Children for their cooperation, and Joe Spradlin for comments on the manuscript.

Address correspondence to William V. Dube, Psychological Sciences Division, University of Massachusetts Medical Center–Shriver Center, 200 Trapelo Road, Waltham, Massachusetts 02452 (E-mail: wdube@shriver.org).

was correlated with the higher rate of reinforcement.

The present study was also conducted with individuals who had severe mental retardation. One of the new contributions of the present study was the evaluation of momentum in a context of self-initiated discrete-trial discrimination tasks, chosen to provide a laboratory model of programmed instruction for special education. Another contribution was the use of variable-ratio (VR) schedules; previous momentum research has typically used VI schedules. As in previous studies, the effects of disrupters were evaluated in conditions in which two components of a multiple schedule provided different obtained reinforcer rates. In addition, subjects were tested in conditions in which the reinforcer rates were similar in both components of the multiple schedules. That is, relative reinforcer rate as a controlling variable for resistance to change was evaluated using within-subject manipulations.

METHOD

Subjects

Subjects were 2 individuals with severe mental retardation. Subject HCB was a 17-year-old female with a mental age-equivalent score of 2 years 7 months on the Peabody Picture Vocabulary Test; Subject MDL was a 20-year-old male with an age-equivalent score of 3 years 2 months. Neither subject received psychoactive medication during the study.

Apparatus and Setting

Each subject sat before a computer monitor with a touch-sensitive screen. A computer controlled all experimental events and data collection, with one exception: Food items were presented after correct responses by an experimenter seated behind and to one side of the subject. Experimental sessions of approximately 10-min duration were conducted 3 or 4 days per week in a small, quiet room at the subjects' school.

Procedure

Discrimination tasks. Each subject was given two discrimination tasks that he or she could perform with high accuracy. High-accuracy tasks were used because frequent errors could reduce obtained reinforcer rates. For all tasks, the stimuli appeared in each of the specified locations equally often in an irregular order.

For Subject HCB, Task A was a simple discrimination, presented on a black background. A white 4.5-cm square with a black cross (2 cm by 2 cm) centered on it appeared in any one of the four corners of the display screen. The correct response was to touch the square; touching a corner of the screen where no stimulus appeared was an incorrect response. Task B was identity matching to sample, presented on a white background. Stimuli were line drawings (2 cm by 2 cm) of a chair, pig, bottle, and shirt. When trials began, one of the stimuli appeared in the center of the screen. Following a touch to the sample, two stimuli appeared in two corners of the screen. One was identical to the sample and touching it was correct; the other stimulus was nonidentical and touching it or a blank corner was an error. During preliminary training, Task B was changed to a single-comparison format in which only the identical comparison stimulus was presented. The task was changed to simplify it after accuracy declined when intermittent reinforcement was introduced (details with the results).

For Subject MDL, Task A was single-comparison identity matching, presented on a white background. Stimuli were the letters S and W, drawn in black. On each trial, a sample stimulus appeared in the center of the screen, and a touch to the sample produced one comparison letter that was identical to the sample in one of the lower corners of the screen. Touching the comparison was the correct response. Task B was presented on a black background. A 4.5-cm red square was presented in the center of the screen. When MDL touched this square, it disappeared and a flashing red square was presented in one of the upper corners of the screen. Touching the flashing square was correct. For both tasks, touching a corner of the screen where no stimulus appeared was an error.

Reinforcer selection. Subjects' teachers suggested food items for reinforcers. Forced-choice pretests with these items were used to identify a food that the subject chose on a majority of opportunities and ate reliably (Dube, McIlvane, Mackay, & Stoddard, 1987). For Subject HCB, the food item was a small piece of chocolate-chip cookie (approximately 1 to 1.5 cm square), and for MDL, it was a piece of cheese-flavored puff (approximately 1 to 2 cm in diameter).

Disrupter selection. Disrupters included videotapes presented on a television screen placed next to the computer monitor (Mace et al., 1990). Tapes were selected after consulting with subjects' teachers: assorted Disney cartoons for Subject HCB and a tape that featured construction equipment for MDL. For HCB, two more alternatives were added during preliminary training: A toy that displayed colored patterns was placed on the tabletop next to the computer monitor, and a portable tape recorder played assorted sound effects. The videotape, toy, and audiotape were presented concurrently during HCB's disrupter sessions.

Consequence procedures. When correct responses were followed by food items, the foods were presented by the experimenter and accompanied by a 1.5-s computer-generated auditory and visual display. When intermittent reinforcement schedules were in effect, the consequence for some correct responses was simply to advance to the intertrial interval (ITI). Incorrect responses (which were rare) were followed by a 1.5-s timeout, during which the computer screen was blank and responses to the touch screen were ineffective, followed by the ITI. During the ITI, the computer screen was blank (white or black, depending on the background color for the current task). The ITI continued until the subject initiated the next trial.

Preliminary training. In initial training, subjects received one (HCB) or two (MDL) 30-trial sessions with Task A, followed by the same number of 30-trial sessions with Task B. During these sessions, the experimenter modeled or prompted trial initiation and correct responses to the touch screen. To initiate trials, Subject HCB pressed the button on a computer mouse that was placed on the table in front of the monitor. Subject MDL could not use a mouse, so he was taught to initiate trials by touching the touch screen during the ITI while the display was blank. Within four sessions, both subjects learned to initiate and complete trials for both tasks independently and with accuracy scores greater than 90% correct.

A multiple schedule was then introduced. Sessions consisted of 60 self-initiated trials, alternating between blocks of 15 trials of Task A and 15 trials of Task B. Over sessions, the task presented first alternated irregularly (either ABAB or BABA). There was a 3-s pause between components; the computer screen was blank during this time. Sessions had these characteristics for the remainder of the experiment.

In the first four multiple-schedule sessions, every correct response for both tasks was followed by a food consequence (continuous reinforcement, CRF), designated as multiple CRF CRF. During one of these sessions, the videotapes to be used as disrupters were evaluated. Videotapes were considered appropriate if the subject appeared to watch them intermittently throughout the session and did not completely stop working on the computer tasks.

After four sessions of multiple CRF CRF, intermittent reinforcement schedules were introduced for Task B. The schedule change was programmed in four steps. In Step 1, the first block of Task B trials was CRF, and the second block included 11 trials followed by a food consequence and four trials followed only by the ITI, a VR 1.36 schedule. In Step 2, the schedule for both blocks of Task B was VR 1.36. In Step 3, the schedule for Task B was VR 2 (eight food consequences in one block and seven in the other block). In Step 4, the schedule was VR 3.75 (four food consequences per block), here rounded to VR 4 for convenience in presentation. Pretraining ended after one session with accuracy greater than 90% with the multiple CRF VR 4 schedule.

Momentum tests. Each momentum test consisted of a baseline condition, two test sessions, and a brief return to the baseline condition. Initial baseline conditions continued until response rates for both tasks were stable for at least five sessions, as judged by visual inspection of the data. Disrupters were presented in the two test sessions, and each possible sequence of components (ABAB or BABA) was used in one test session. Following the test sessions, baseline conditions were reinstated for two to four sessions to confirm that any changes in response rates during the tests were due to the disrupters.

The disrupters were (a) prefeeding, (b)

presenting response-independent food between components of the multiple schedule, and (c) providing potentially reinforcing alternatives to the discrimination tasks. All three disrupters were presented in every test session. Subject HCB was given two cookies immediately prior to the session and one cookie between components. MDL was given 10 cheese puffs immediately prior to the session and three cheese puffs between components. For prefeeding, the experimenter waited until the food was consumed before starting the session. Between components, the experimenter presented the food and then initiated the next component immediately by pressing a switch. The task alternatives, described earlier, were videotapes for both subjects plus a toy and sound effects for HCB. Videotapes and HCB's audiotape began immediately after the first trial of the first component and continued throughout the remainder of the session. Before the first test session, the experimenter said to the subject, "Sometimes there will be a TV here, like today. It's okay for you to watch TV while you work, if you want to." Before subsequent test sessions, subjects were told, "The TV is here again today. It's okay for you to watch TV while you work, if you want to."

Subjects HCB and MDL received three and four momentum tests, respectively. The baseline reinforcement schedule for both subjects' initial test was multiple CRF VR 4. MDL received a second test with a baseline schedule of multiple CRF VR 15 (details with the results). Both subjects were then tested with a baseline schedule of multiple CRF CRF, followed by a final test with the previous multiple CRF VR schedule.

RESULTS

Preliminary Training

Subject HCB's preliminary training required 23 sessions. When the multiple CRF VR 4 schedule was introduced, accuracy scores for Task B abruptly declined to 60% to 67% for three sessions. With a return to multiple CRF CRF, accuracy recovered to 100% in two sessions. Task B was then modified to the single-comparison procedure, and accuracy remained high when the VR 4 schedule was reintroduced. Following the change in Task B, the videotape pretest was repeated and, because she did not appear to watch the videotape reliably, the toy and sound effects were added as task alternatives for momentum test sessions.

Subject MDL completed pretraining in 14 sessions. His accuracy was nearly always perfect. Three of his early sessions were terminated early because of problems during the session (e.g., self-injurious behavior), so he was given three extra sessions of multiple CRF CRF to provide a more stable history before introducing intermittent reinforcement.

Momentum Tests

For each session, separate response rates for Tasks A and B were calculated by dividing the total number of trials completed for each task (30) by the total time spent working on that task (summed across the two blocks of 15 trials). The upper portions of Figures 1 and 2 show response rates for Task A and Task B. For each subject, the first baseline session shown is the final session of preliminary training.

Obtained reinforcer rates were calculated by dividing the total number of reinforcing consequences for each task by the total duration of that task. The middle portions of Figures 1 and 2 show the reinforcer-rate ratios, the rate for Task A divided by the rate for Task B, plotted on a log scale.

The lower portions of Figures 1 and 2 show the decrease in response rates from baseline to test sessions as a proportion of baseline response rate. Within each plot, the points on the left show log(baseline/baseline), which is always zero, and the points on the right show log(test/baseline). Table 1 shows mean accuracy scores, response rates, and reinforcer rates.

Subject HCB. The data in Table 1 show that HCB's accuracy scores were greater than 90% in every condition, except for the test sessions in the multiple CRF CRF condition. Table 1 also shows that errors resulted in minor differences between response rates and obtained reinforcer rates for CRF schedules.

Data in the upper left portion of Figure 1 show stable baseline response rates for Subject HCB on the multiple CRF VR 4 schedule, the decrease in response rates during the first test, and the subsequent recovery after the test. As shown in the middle portion of Fig-

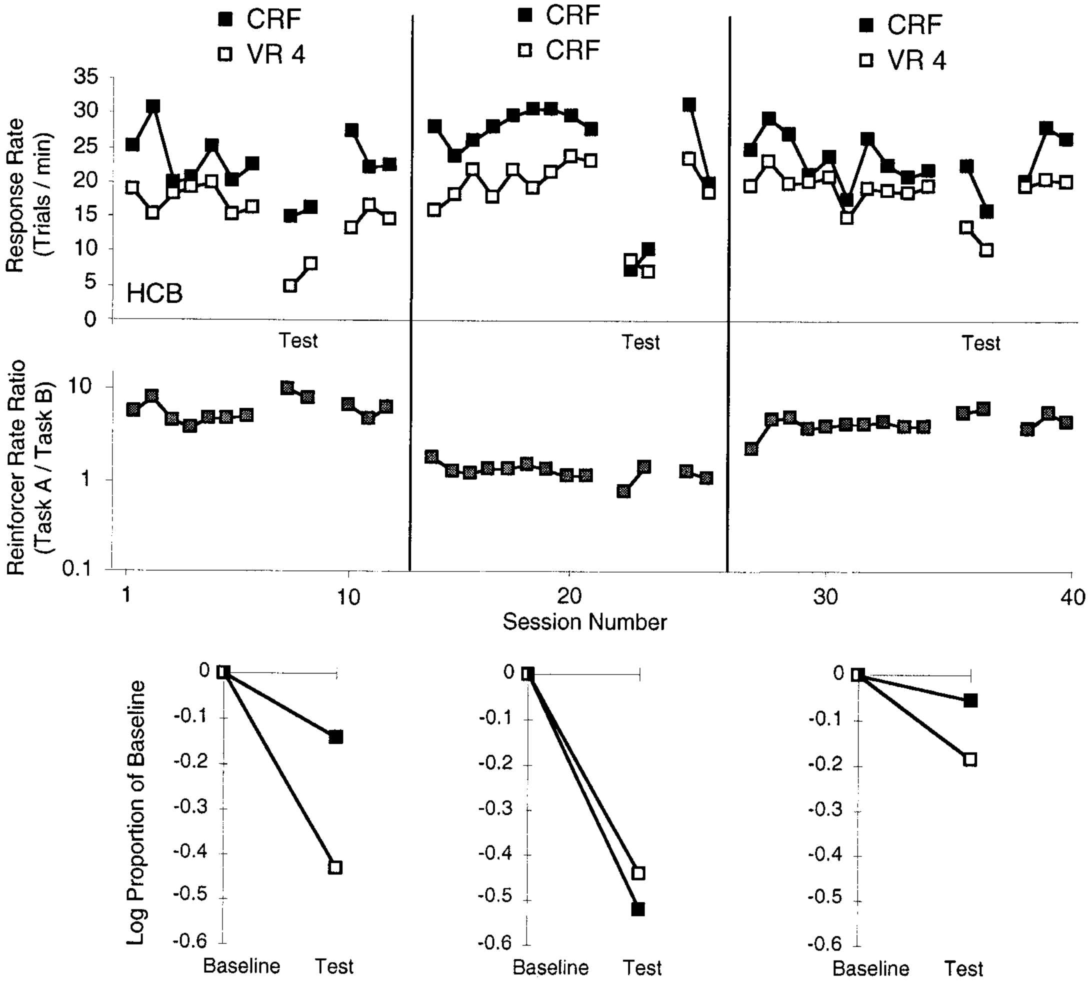

Fig. 1. Results for Subject HCB. The upper portion shows response rates (trials per minute) for Task A (filled points) and Task B (open points) in successive sessions. Gray points in the center portion show obtained reinforcer-rate ratios, the rate for Task A divided by the rate for Task B. Rate ratios for each session are plotted on a log scale. Plots in the lower portion show results of momentum tests as the log proportion of baseline response rate. Data for Tasks A and B are shown as filled and open points, respectively. Baseline response rate is the mean for the last five baseline sessions immediately prior to the test, and test response rate is the mean for the two test sessions.

ure 1, the reinforcer-rate ratio (Task A/Task B) for the last five sessions of the first baseline condition was greater than 4.0. For the multiple CRF VR 4 momentum test, the lower left portion of Figure 1 shows that the proportional decrease in response rate for Task B was more than twice that for Task A.

The center portions of Figure 1 show the data for the multiple CRF CRF condition. Response rates for both tasks were slightly higher than those in the previous condition. The baseline reinforcer-rate ratio was less than 2.0, and the proportional decrease in response rate during the test sessions was slightly greater for Task A than for Task B. That is, when reinforcer rates were approximately equal, the momentum effect disappeared.

The right portions of Figure 1 show that a return to the multiple CRF VR 4 schedule once again resulted in baseline reinforcer ratios greater than 4.0 and, during test sessions, a proportionally greater decrease in response rates for Task B than for Task A. Taken together, the data for HCB show that behavior maintained by higher rates of reinforcement had greater resistance to change, and that rel-

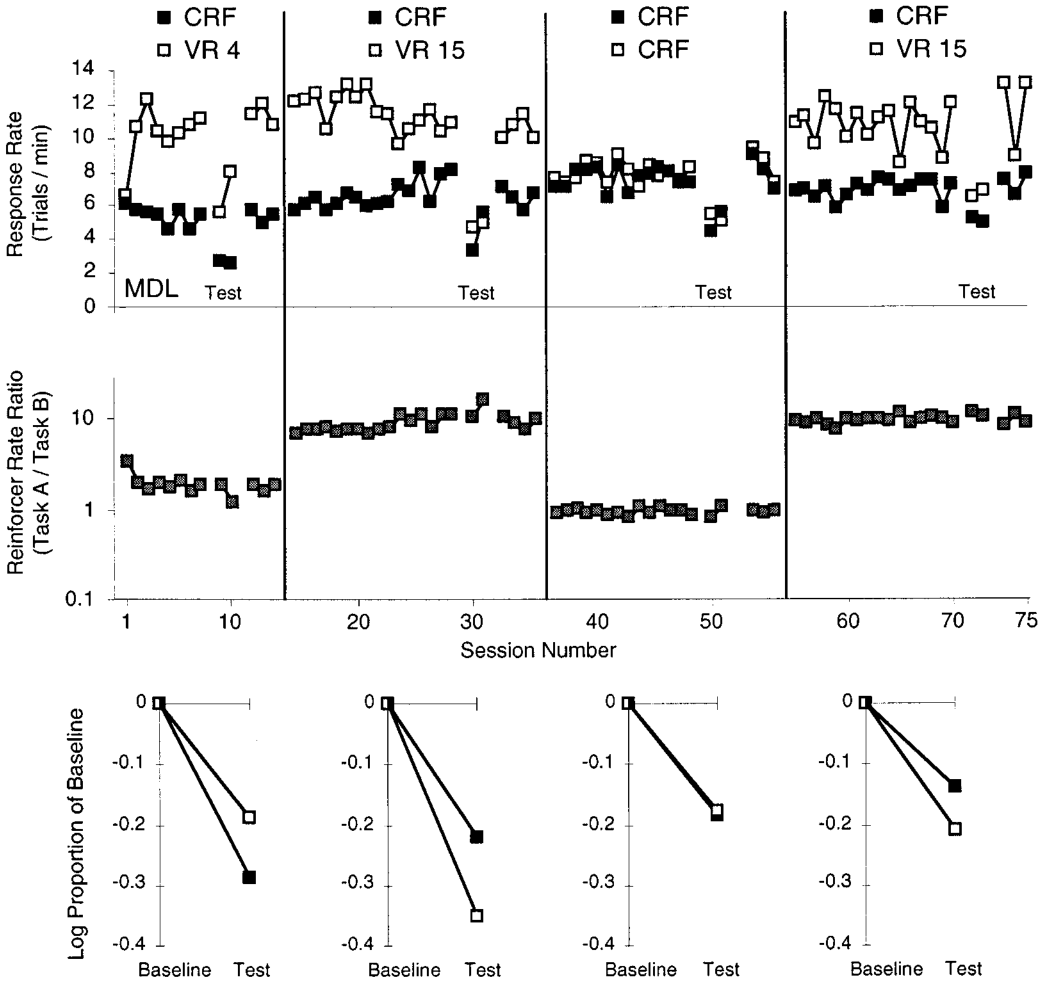

Fig. 2. Results for Subject MDL. See Figure 1 caption for details.

ative reinforcer rate was the controlling variable.

Subject MDL. Figure 2 shows the data for Subject MDL. During the initial multiple CRF VR 4 condition, the response rate for Task B (VR 4) was approximately twice that for Task A (CRF; see Table 1 and the upper left portion of Figure 2). Because the response rate was higher for the task with the leaner schedule, the difference between obtained reinforcer rates for the two tasks was substantially smaller than the difference between the programmed schedules. The ratio (Task A/Task B) for the programmed schedules was 4.0, and the center portion of Figure 2 shows that the obtained reinforcer ratio was slightly less than 2.0 (mean for the last five baseline sessions was 1.89). The lower left portion of Figure 2 shows that during the first test, response rates for Task A, with the lower baseline response rate, decreased more relative to baseline than did those for Task B, with the higher baseline rate.

MDL's second condition was multiple CRF VR 15. The schedule disparity was increased to increase differences in obtained reinforcer rates. The upper portion of Figure 2 shows that response rates for Task A (CRF) increased slightly, which contributed to the difference in reinforcer rates. During the last five baseline sessions before the test, the reinforcer-rate ratio was approximately 10.0. During the test sessions, the relative change in response rates reversed from the previous

Table 1

Accuracy scores, response rates (trials per minute), and reinforcer rates (reinforcers per minute). Baseline accuracy scores and rates are means for the last five baseline sessions in each condition. Test accuracy scores and rates are means for the two test sessions. Session numbers correspond to Figures 1 and 2.

Subject	Condition		Session numbers	Accuracy score (%) Task A	Accuracy score (%) Task B	Response rate Task A	Response rate Task B	Reinforcer rate Task A	Reinforcer rate Task B
HCB	Mult CRF VR 4	Baseline	3–7	99	99	21.7	17.8	21.4	4.6
		Test	8–9	93	97	15.7	6.7	14.7	1.6
	Mult CRF CRF	Baseline	17–21	97	99	29.8	22.0	29.0	21.7
		Test	22–23	85	88	9.0	8.0	7.7	7.0
	Mult CRF VR 4	Baseline	31–35	96	99	21.9	18.4	21.0	4.9
		Test	36–37	95	92	19.3	12.0	18.2	3.0
MDL	Mult CRF VR 4	Baseline	4–8	100	100	5.3	10.5	5.3	2.8
		Test	9–10	100	100	2.7	6.9	2.7	1.8
	Mult CRF VR 15	Baseline	25–29	100	100	7.5	11.0	7.5	0.7
		Test	30–31	100	100	4.5	4.9	4.5	0.3
	Mult CRF CRF	Baseline	45–49	100	100	7.8	8.0	7.8	8.0
		Test	50–51	100	100	5.1	5.3	5.1	5.3
	Mult CRF VR 15	Baseline	66–70	100	100	7.1	10.9	7.1	0.7
		Test	71–72	100	100	5.2	6.7	5.2	0.4

condition; the decrease in response rates became greater for Task B (VR 15) than for Task A (CRF).

The remainder of MDL's data in Figure 2 are consistent with the findings for Subject HCB. When the schedule was changed to multiple CRF CRF, response rates became similar for both tasks, the reinforcer ratio was approximately 1.0, and the decrease in response rates during test sessions was similar for both tasks. Following a return to the multiple CRF VR 15 schedule, the reinforcer ratio was again approximately 10.0, and response rates decreased more for Task B (VR 15) than Task A (CRF) during the test sessions.

DISCUSSION

This experiment demonstrated behavioral momentum effects in individuals with severe mental retardation. In every condition in which obtained reinforcer ratios were greater than 2.0, resistance to change was greater in the component with the higher reinforcer rate. When reinforcer-rate ratios were more similar, resistance to change also was more similar. These results extend previous findings with humans by isolating relative reinforcer rate as a controlling variable via within-subject manipulations, and by showing momentum effects with self-initiated discrimination tasks and VR reinforcement schedules.

When obtained reinforcer-rate differences were small, resistance to change was strictly consistent with the momentum analysis in only one of three cases: Subject MDL's multiple CRF CRF test. In that case, the baseline reinforcer rates were equal (ratio = 0.98, data from Table 1) and disruption was equal (Figure 2).

In two other cases, small reinforcer-rate differences produced results that were somewhat inconsistent with the momentum analogy. One case was Subject HCB's multiple CRF CRF test, which followed a reinforcer-rate ratio of 1.34. Although the difference in disruption as a proportion of baseline was much smaller than in HCB's other conditions, disruption was slightly greater for the task with the slightly higher reinforcer rate. The second case was Subject MDL's initial condition (multiple CRF VR 4). The baseline reinforcer-rate ratio was 1.89, and disruption was greater for the task with the higher reinforcer rate. Our use of ratio schedules may be relevant to this discrepancy. In ratio schedules, response rates and reinforcer rates are related, and higher response rates produce higher reinforcer rates. Thus, the reinforcement contingencies of the present experiment had the potential to establish presentation of the Task B stimuli as discriminative for behavioral acceleration, thereby increasing the response rate relative to Task A. In fact, just prior to MDL's initial momentum test, his response rate for Task B was twice that for Task A. MDL's results in the initial CRF VR 4 condition may reflect the combined effects of a relatively small difference in obtained reinforcer rates plus stimulus control of behavioral acceleration by Task B stimuli. Future studies might examine possible interactions between schedule type and the measurement of behavioral momentum.

The context for the present study was a laboratory model of computer-assisted programmed instruction for special education (e.g., Dube & Serna, 1998; McIlvane, 1992). Relevant features included self-paced discriminations presented on a touch screen equipped monitor, continuous or ratio reinforcement schedules, and individualized reinforcing stimuli. The disrupters for the behavioral momentum tests (response-independent reinforcer presentations and the availability of potentially reinforcing alternatives to the discrimination tasks) also occur routinely in educational settings. We asked whether momentum effects would be demonstrated in this context because of the possibility that momentum analyses may help in understanding learning problems that often arise in such situations.

Given our initial positive results, continued research may ask more specifically whether behavioral momentum effects are relevant to issues in discrimination learning, and how they may find application in teaching developmentally limited populations (e.g., Mace, 1996). Central to any such application is the premise that discrimination learning procedures may generate multiple sources of stimulus control or multiple stimulus control topographies (e.g., Dube & McIlvane, 1996; McIlvane, Serna, Dube, & Stromer, 2000; Ray, 1969; Sidman, 1980; Stoddard & Sidman, 1971). Some learning problems may be traced to competition between stimulus control topographies. Examples include failures to transfer stimulus control from prompts to target stimuli (Kennedy, 1992), difficulties in training within-session discrimination reversals (McIlvane, Kledaras, Iennaco, McDonald, & Stoddard, 1995), and gradual emergence of stimulus equivalence classes (Dube & McIlvane, 1996). In each case, analysis of the problem may implicate the persistence of previously established behavior that competes with the desired behavior. The momentum analysis suggests that one might decrease the persistence of competing behavior by reducing the rate of reinforcement in situations in which the controlling stimuli for that behavior are presented alone.

To consider one of the examples above, prompting procedures typically use continuous reinforcement schedules. Thus, behavior controlled by prompts may have substantial momentum, and the stimulus–reinforcer relations may encourage successful competition by prompts as controlling stimuli (McIlvane & Dube, 2000). The momentum analysis predicts that the resistance to change of prompt-controlled behavior should be a function of the rate of reinforcement during prompted trials. If continued research confirms that the aggregate rate of reinforcement determines resistance to change in such situations, the results will have important implications for teaching practice. For example, providing additional reinforcement for remaining on task or attending to instructional stimuli during prompting sequences may have an undesirable side effect. It may increase resistance to change for behavior controlled by prompts and thus contribute to problems of prompt elimination and stimulus control transfer.

To conclude, we note that our data and speculations about perhaps unappreciated momentum influences raise larger issues and questions for clinical and educational research. For example, should initial assessment of behavioral momentum be a standard practice when designing contingencies to encourage behavior change? When feasible, behavior that has substantial momentum might be countered by arranging exceptionally discriminable and reinforcing teaching contingencies. A related set of questions concerns the status of behavior that has a long history in the individual's repertoire. One might expect such behavior to be highly resistant to change. Another possibility, however, is that the persistence of such behavior might be related to the maintaining schedule and not to the length of the behavioral history per se. In this optimistic view, some longstanding ineffective or aberrant behavior may in fact be maintained only weakly, reflecting merely a relative lack of access to contingencies that maintain more constructive behavioral repertoires (Ferster, 1961; cf. Saunders & Spradlin, 1991). On the other hand, longstanding behavior may indeed have substantial momentum, and a different set of behavior-change contingencies may be required in such situations. Skilled clinicians and educators may intuitively recognize the difference between these situations and try to adjust their behavior accordingly. Nevin's insights may have set the stage for understanding such problems scientifically and for developing a range of treatment options that might not have been otherwise obvious.

REFERENCES

Cohen, S. L. (1996). Behavioral momentum of typing behavior in college students. *Journal of Behavior Analysis and Therapy, 1,* 36–51.

Dube, W. V., Mazzitelli, K., Lombard, K. M., & McIlvane, W. J. (2000). Assessing behavioral momentum in humans with mental retardation and unstable baselines. *Experimental Analysis of Human Behavior Bulletin, 18,* 6–11.

Dube, W. V., & McIlvane, W. J. (1996). Some implications of a stimulus control topography analysis for emergent stimulus classes. In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 197–218). Amsterdam: Elsevier.

Dube, W. V., McIlvane, W. J., Mackay, H. A., & Stoddard, L. T. (1987). Stimulus class membership established via stimulus-reinforcer relations. *Journal of the Experimental Analysis of Behavior, 47,* 159–175.

Dube, W. V., & Serna, R. W. (1998). Reevaluation of a programmed method to teach generalized identity matching to sample. *Research in Developmental Disabilities, 19,* 347–379.

Ferster, C. B. (1961). Positive reinforcement and behavioral deficits of autistic children. *Child Development, 32,* 437–456.

Grace, R. C., & Nevin, J. A. (1997). On the relation between preference and resistance to change. *Journal of the Experimental Analysis of Behavior, 67,* 43–65.

Kennedy, C. H. (1992). Concurrent operants: A model for stimulus control transfer using delayed prompting. *The Psychological Record, 42,* 525–540.

Mace, F. C. (1996). In pursuit of general behavioral relations. *Journal of Applied Behavior Analysis, 29,* 557–563.

Mace, F. C., Lalli, J. S., Shea, M. C., Lalli, E. P., West, B. J., Roberts, M., & Nevin, J. A. (1990). The momentum of human behavior in a natural setting. *Journal of the Experimental Analysis of Behavior, 54,* 163–172.

Mace, F. C., Lalli, J. S., Shea, M. C., & Nevin, J. A. (1992). Behavioral momentum in college basketball. *Journal of Applied Behavior Analysis, 25,* 657–663.

McIlvane, W. J. (1992). Stimulus control analysis and nonverbal instructional methods for people with intellectual disabilities. In N. W. Bray (Ed.), *International review of research in mental retardation* (Vol. 18, pp. 55–109). San Diego: Academic Press.

McIlvane, W. J., & Dube, W. V. (2000). Behavioral momentum and multiple stimulus control topographies [Commentary]. *Behavioral and Brain Sciences, 23,* 109.

McIlvane, W. J., Kledaras, J. B., Iennaco, F. M., McDonald, S. J., & Stoddard, L. T. (1995). Some possible limits on errorless discrimination reversals in individuals with severe mental retardation. *American Journal on Mental Retardation, 99,* 430–436.

McIlvane, W. J., Serna, R. W., Dube, W. V., & Stromer, R. L. (2000). Stimulus control topography coherence and stimulus equivalence: Reconciling test outcomes with theory. In J. Leslie & D. E. Blackman (Eds.), *Experimental and applied analysis of human behavior* (pp. 85–110). Reno, NV: Context Press.

Nevin, J. A. (1992). An integrative model for the study of behavioral momentum. *Journal of the Experimental Analysis of Behavior, 57,* 301–316.

Nevin, J. A. (1996). The momentum of compliance. *Journal of Applied Behavior Analysis, 29,* 535–547.

Nevin, J. A., & Grace, R. C. (2000). Behavioral momentum and the law of effect. *Behavioral and Brain Sciences, 23,* 73–130.

Nevin, J. A., Mandell, C., & Atak, J. R. (1983). The analysis of behavioral momentum. *Journal of the Experimental Analysis of Behavior, 39,* 49–59.

Nevin, J. A., Tota, M. E., Torquato, R. D., & Shull, R. L. (1990). Alternative reinforcement increases resistance to change: Pavlovian or operant contingencies? *Journal of the Experimental Analysis of Behavior, 53,* 359–379.

Plaud, J. J., & Gaither, G. A. (1996). Human behavioral momentum: Implications for applied behavior analysis and therapy. *Journal of Behavior Therapy and Experimental Psychiatry, 27,* 139–148.

Ray, B. A. (1969). Selective attention: The effects of combining stimuli which control incompatible behavior. *Journal of the Experimental Analysis of Behavior, 12,* 539–550.

Saunders, R. R., & Spradlin, J. E. (1991). A supported routines approach to active treatment for enhancing independence, competence and self-worth. *Behavioral Residential Treatment, 6,* 11–37.

Sidman, M. (1980). A note on the measurement of conditional discrimination. *Journal of the Experimental Analysis of Behavior, 33,* 285–289.

Stoddard, L. T., & Sidman, M. (1971). The removal and restoration of stimulus control. *Journal of the Experimental Analysis of Behavior, 16,* 143–154.

Received December 14, 1998
Final acceptance November 5, 2000

∫QAB Society for the Quantitative Analyses of Behavior

Annual Meeting, May 25-26, 2001
Hyatt Regency Hotel, New Orleans

Friday, May 25

John Staddon	*Duke University*, The dynamics of interval timing
Amy Odum	*University of New Hampshire*, Behavioral pharmacology and timing
Geoffrey White	*University of Otago*, Temporal generalization and diffusion in forgetting
Kim. Kirkpatrick	*York University*, Packet theory of conditioning and timing
William Roberts	*University of Western Ontario*, Timing and counting by pigeons: Do they require similar or different mechanisms?
Richard Keen	*Indiana University*, Relative numerosity discrimination and short-term memory
Allen Neuringer	*Reed College*, Operant variability and a theory of operant behavior.
Alexandra Logue	*Baruch College, City University of New York*, Self-control, impulsiveness, and higher education administration
Howard Rachlin	*Stony Brook*, Teaching and learning in the prisoner's dilemma
John Kraft	*Armstrong Atlantic State University*, Quantifying human social behavior with the Ideal Free Distribution model
Anthony McLean	*University of Canterbury*, Extraneous reinforcement, response rate and resistance to change
Randolph Grace	*University of Canterbury*, Acquisition of preference: comparing representational and linear operator models
William Baum	*University of New Hampshire*, Analysis of visits in the dynamics of choice

Saturday Morning, May 26

Ralph Miller	*Binghamton*, Interference between cues and between outcomes presented together and presented apart
Douglas Williams	*University of Winnipeg*, Input coding in animal and human associative learning
Tony Nevin	*University of New Hampshire*, Behavioral Momentum: measurement properties of force and mass
John Donahoe	*University of Massachusetts*, On neuroscience and behavioral analysis.

Saturday Afternoon, May 26
Invited Preeminent Tutorials: From basics to contemporary paradigms

Author	**Affiliation**	**Title**	**Discussant**
Michael Davison.	*Auckland University*	What Reinforcers Do To Behaviour	William Baum
Randolph Grace	*University of Canterbury*	Quantification	John Nevin
William Timberlake	*Indiana University*	Behavior Systems	Donald Patterson
Leonard Green	*Washington University*	The Discounting Function	Michael Davison

For further information, visit the ∫QAB web page at http://sqab.psychology.org or contact Armando Machado, ∫QAB Program Chair, at armandom@iep.uminho.pt